

Institution: University of Bristol		
Unit of Assessment: 14) Geography and Environmental Studies		
Title of case study: Driving emissions reductions by developing scientific methods for the reporting of greenhouse gases and ozone depleting substances		
Period when the underpinning research was undertaken: 2000-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr Anita Ganesan	NERC Research Fellow and Senior Lecturer	10/2013 – present
Dr Jo House	Reader in Environmental Science and Policy	08/2004 – present
Dr Matthew Rigby	Reader in Atmospheric Chemistry	01/2012 – present
Period when the claimed impact occurred: 2017-2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Accurate monitoring and verification of reported fluxes of pollutants incentivises genuine and measurable reductions in emissions. The University of Bristol has provided evidence of poor practice and non-compliance with international climate change and ozone layer protection agreements, which has led directly to reductions in harmful emissions of greenhouse gases (GHGs) and ozone depleting substances, and to changes in reporting processes. Working at the national and international scale, the research has developed new measurements and models to improve the accuracy and credibility of emissions reporting, leading to:

1. The identification of the first major breach of the Montreal Protocol on Substances that Deplete the Ozone Layer and a subsequent elimination of those activities from China following enforcement action.
2. New measurements and methods to support GHG emissions reporting under the Paris Agreement and Kyoto Protocol, used by governments in the UK and India.
3. New accounting methods for carbon emissions legislated under EU regulation No 2018/841 on Land Use, Land Use Change and Forestry.

2. Underpinning research

National and international policies tackling climate change and damage to the ozone layer require countries to report emissions of greenhouse gases (GHGs) and production of Ozone Depleting Substances (ODS) to international bodies. For example, the UNFCCC (United Nations Framework Convention on Climate Change) requires GHG “monitoring, reporting and verification” methods that are “transparent, consistent, comparable, credible and accurate” in order to incentivise action that leads to genuine emissions reductions or the removal of GHGs from the atmosphere (sinks). Similarly, the Montreal Protocol has banned many ODSs and has heavily regulated others, thus requiring countries to report any production of ODSs. However, some estimates are currently mis-reported or have high uncertainty such that opportunities for actions to tackle climate change and ozone depletion are being missed. GHG reporting follows methodological guidance provided by the Intergovernmental Panel on Climate Change (IPCC) Inventory Guidelines. From 2020, the UN’s Paris Agreement will take over from the Kyoto Protocol and requires all 189 signatory countries to have stronger reporting requirements, making the provision of robust methods and the accessibility of data more important for delivering scientifically credible emissions reductions. The University of Bristol (UoB) team have worked with inventory compilers, policy makers and industry to create novel methods using inventories, models, and atmospheric data to assess non-compliance of international agreements and verify the accuracy of emissions reporting, as follows:

1. Identifying CFC-11 emissions from China’s illegal production

CFC-11 is one of the most important ODSs that destroys the ozone layer, and also impacts the climate as a potent GHG. The international Advanced Global Atmospheric Gases Experiment (AGAGE) network (of which UoB leads two of the five core stations) [1] has been world-leading in

the measurement and modelling of GHGs and ODSs since 1978. Modelling techniques developed by UoB researchers coupled with AGAGE measurements from international collaborators were used to identify a rise in emissions of the banned ODS, CFC-11, from eastern China [2]. UoB research showed that China's emissions made up 60% of the global rise in CFC-11 emissions after 2012 and demonstrated that illegal new production of CFC-11 was likely taking place in China, which had not been reported to the United Nations Environment Programme (UNEP) [2]. In their most recent research, the UoB team show that China's CFC-11 emissions decreased by 60% following enforcement action (Park et al including Ganesan, Rigby, A decline in emissions of CFC-11 and related chemicals from eastern China, *Nature*, accepted 11/20).

2. Verifying national GHG and ODS emissions inventories

UoB has led the development of a globally unique GHG and ODS emissions observation network in the UK and Ireland under the UK Deriving Emissions related to Climate Change (DECC Network) [3]. The DECC network, designed and implemented by the UoB team, is distinguished by its capacity to make high-frequency measurements of all of the key gases that are regulated by the Kyoto and Montreal Protocols. This makes the UK atmosphere one of the most densely sampled of any country in the world. The geographical and statistical modelling of these atmospheric measurements has shown that the UK emissions inventory is consistent with the atmospheric record for some gases but is missing important emissions information for others, such as nitrous oxide [3].

UoB researchers also developed a new satellite-based observation method to estimate India's methane emissions and independently compare them with data in its methane inventory [4]. They found India's methane inventory to be accurate, which improved confidence in methane emission estimates included in India's GHG inventory under its UNFCCC reporting obligations. This study also demonstrated how satellite data can be used to estimate emissions in resource-poor countries where extensive ground-based measurement stations do not exist.

3. Credible methods to avoid false accounting of GHG emissions from forestry

The UoB research team also co-developed a new methodological approach for forest GHG accounting across the EU and internationally [5]. Under the Kyoto Protocol, developed countries gain credits or debits if net forest emissions decrease or increase, respectively, with changes calculated in relation to Forest Reference Levels. The research showed that current EU Forest Reference Levels incorrectly included possible future policies to increase harvest. Had harvesting actually increased, then any associated GHG emissions would not be accounted for. If the increased harvesting did not happen (as now seen at the close of the Kyoto commitment period), the EU would gain false carbon credits of 70-80MtCO₂ (worth around EUR2 billion) [5]. The approach uses historical forest management practices and age structures in a transparent and scientifically credible way to ensure accounting fully reflects the impact of actual changes in management activity [5] and does not limit the development of forest-based bioeconomy [6].

3. References to the research

1. Prinn RG *et al.* including **Ganesan AL** (2018). History of chemically and radiatively important atmospheric gases from the Advanced Global Atmospheric Gases Experiment (AGAGE), *Earth System Science Data*, **10**, pp.985-1018, <https://doi.org/10.5194/essd-10-985-2018>
2. **Rigby M** *et al.* including **Ganesan AL** (2019). Increase in CFC-11 emissions from eastern China based on atmospheric observations, *Nature*, **569**, pp.546–550 <https://doi.org/10.1038/s41586-019-1193-4>
3. **Ganesan AL** *et al.* (2015). Quantifying methane and nitrous oxide emissions from the UK and Ireland using a national-scale monitoring network, *Atmospheric Chemistry and Physics*, **15**, pp.6393–6406, <https://doi.org/10.5194/acp-15-6393-2015>
4. **Ganesan AL**, **Rigby M** *et al.* (2017). Atmospheric observations show accurate reporting and little growth in India's methane emissions, *Nature Communications*, **8**(836), <https://doi.org/10.1038/s41467-017-00994-7>
5. Grassi G, Pilli R, **House J** *et al.* (2018). Science-based approach for credible accounting of mitigation in managed forests, *Carbon Balance and Management*, **13**(8), <https://doi.org/10.1186/s13021-018-0096-2>

6. Grassi G, Camia A, Fiorese G, **House J et al.** (2018). Wrong premises mislead the conclusions by Kallio et al. on forest reference levels in the EU, *Forest Policy and Economics*, **95**, pp.10-12, <https://doi.org/10.1016/j.forpol.2018.07.002>

Grant evidence

- **Rigby (PI), Ganesan and House (Co-Is)**, *Detection and Attribution of Regional greenhouse gas Emissions in the UK (DARE-UK)*, NERC Highlight Topic, 2019-2023, Bristol share GBP993,457
- **Ganesan (Co-I)**, *UK DECC Network*, Department of Business, Energy and Industrial Strategy, 2018-2021, Bristol share GBP1.87 million
- **Ganesan (PI)**, *South Asian methane emissions, inferred from surface, aircraft and satellite observations*, NERC Independent Research Fellowship, 2015-2021, Bristol share GBP392,088
- **House (Co-I)**, *VERIFY: Observation-based system for monitoring and verification of greenhouse gases*, European Commission Horizon 2020 H2020-EU.3.5.1 Programme 2018-2022, EUR10 million, Bristol share: EUR105,392
- **House (PI)**, *Greenhouse Gas Removal in the Land Sector - Addressing the Gaps (GGRiLS - Gaps)*, NERC Greenhouse Gas Removal Programme, 2018-2020 , GBP242,526

4. Details of the impact

UoB's research strengthened tools for assessing the accuracy of GHG and ODS reporting. It has delivered impact in a range of arenas, from national to international level, including the identification and reduction of illegal CFC production from China, improved national GHG inventory approaches to report and evaluate GHG emissions under the United Nations Framework Convention on Climate Change (UNFCCC) in the UK and India, and the adoption of new forest carbon accounting methods in EU legislation.

1. Identification and reduction of illegal CFC-11 production from China

The 31st Meeting of the Parties (MOP31) to the Montreal Protocol in November 2019 [a] noted that “research [2] had determined that 40-60% of these global [CFC-11] emission increases had originated in eastern China.”. MOP31 also remarked that, until publication of the UoB work, “it was troubling that, for at least five years, there had been substantial amounts of unexplained emissions of CFC-11 that were not consistent with actions taken under the Montreal Protocol.” These “unnoticed” emissions have the potential to delay the disappearance of the ozone hole by several years and in terms of their impact on climate, are equivalent to the carbon dioxide emission rate from London. At MOP31 and meetings of the UN Multilateral Fund, delegates from China outlined law enforcement activities that occurred after Bristol’s demonstration of non-compliance, that illegal production facilities had been shut down and some ODSs, including CFC-11, had been seized. They noted that “numerous cases of illegal production facilities had been found in China” [a]. Preliminary findings presented at MOP31 and later confirmed in the UoB team’s latest *Nature* paper (Park et al., accepted 11/20) show that “CFC-11 emissions have declined both globally and from eastern China since the 2014-2017 period” [a] suggesting that these enforcement activities, initiated following UoB research, have been successful. To ensure that such breaches are detected and stopped more rapidly in the future, China has taken actions “including strengthening legislation and building capacity, including through improved access to monitoring equipment, inspections of plants and establishment of a monitoring plan” [a]. At the Open-Ended Working Group of the Parties to the Montreal Protocol in July 2019 [a], China’s delegates stated that “It had also begun amending legislation governing the management of ozone-depleting substances. They were listed as harmful substances, and all illegal dumping, emissions and processing would be subject to criminal proceedings. In addition, controls on the raw materials required to produce CFC-11 had been tightened.”

2. A gold standard for national inventory evaluation

UoB’s work on developing new GHG estimation methods [3,4] now underpins the approaches that both the UK and India use to report and evaluate GHG emissions under the United Nations Framework Convention on Climate Change (UNFCCC). In the UK, the information derived from

the UK DECC Network (led by UoB with 70% of funding to UoB) feeds directly to the Department of Business, Energy and Industrial Strategy (BEIS) inventory team, which uses the measurement-derived emissions of GHGs to compare with the national inventory estimates each year. The UK National Inventory Report is modified, if required, and UoB's results are published within it [b]. As described in a letter from BEIS, *"The DECC network has been instrumental in informing and improving the GHGI [UK Greenhouse Gas Inventory]....Where the DECC network and GHGI are in good agreement, this provides the UK with increased confidence in the numbers we report in the inventory. Where there are discrepancies, we investigate to find the reasons why"* [c]. The UK is one of only four countries in the world to verify its emissions inventories in this way and improve its inventory based on atmospheric modelling.

Further documented in the letter from BEIS: *"The largest impact of the Bristol-led DECC network is the benefit it provides to the UK's international standing. DECC network staff have used their expertise in international work in the field, including helping other countries like Australia implement similar programmes. They have also been central to drafting new best practice guidance for inventory compilation, using our work as a case study. With increased emphasis under the Paris Agreement on countries monitoring and evaluating their emissions, the UK's successful example of bringing together policy makers, inventory compilers and atmospheric scientists will provide further opportunities to lead the world in this field."* [c]. The UK DECC Network was highlighted as an exemplar of a country implementing independent emissions assessment at the World Meteorological Organization (WMO) Integrated Global Greenhouse Gas Information System (IG3IS, Ganesan is a Steering Committee member) [c] and in the 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories [d]. The WMO IG3IS calls for countries to *"build on the example of "early movers" countries like UK"* (Australia has since followed UoB's methods, as described in the letter from BEIS [c], see above) and this implementation plan has been adopted by the Subsidiary Body for Scientific and Technological Advice to the UNFCCC [c].

Building on the expertise in the UK, and using the results of UoB's study [4], India became the first non-Annex 1 (i.e. developing) country to report emissions of the major GHG methane derived from atmospheric measurements in its National Communications to the UNFCCC. In India's Second Biennial Update Report (BUR) to the UNFCCC [b], it states *"A paper published in Nature Communications [4] investigated India's methane emissions using a top-down approach and concluded that the magnitude of India's methane emissions was consistent with that reported in First BUR."* The incorporation of this information provides Indian inventory compilers and policy makers with independent information with which to evaluate their emissions, thus improving the accuracy of their submissions. This research provided a proof-of-concept for the methodology that can be applied in the 154 developing countries that do not have extensive data collection, and is noted in the 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories [d].

3. New forest carbon accounting methods in EU legislation incentivises lower emissions

The research and new method [5] were initially presented in a 2017 European Commission Joint Research Centre (JRC) technical paper [e]. It was subsequently incorporated into an "EU Commission proposal" negotiated by EU Environment Council ministers and became part of the LULUCF Regulation No 2018/841 (June 2018) [e]. All EU countries are legally bound to use this method for setting updated Forest Reference Levels (FRL) under the Paris Agreement. The Technical Guidance published alongside the regulations [e] states that *"the [new] FRL...excludes assumptions of forest management development or expectations on future demand for wood or land use ... similar to the accounting of GHGs on other sectors (Grassi et al. 2018, [5])."* Negotiations were highly controversial with pressure from countries with large forest industries to use approaches that would hide the atmospheric impact of harvest [6]. The senior vice-president of the Swedish Forest Industries Federation stated *"When applying ...the Commission's proposal ... Sweden will need to compensate for [forest harvest] emissions"* [f], that is reduce emissions from other sectors. To ensure that the science regarding the risks of false accounting shaped EU legislation, UoB led a EURACTIV publication/letter based on their research and supported with signatures of 40 international experts [f]. The letter, published June 2017, was translated into

several EU languages and sent to over 50 EU policy makers. Shortly afterwards, a letter from the German Secretary of State to the EU Climate Commissioner [g] stated “we see *this regulation as a crucial building block of the EU’s climate ambition and international credibility. It’s important that the EU sets an example of robust accounting... the accounting rules as proposed by the commission... constitute a reliable and transparent framework... and set the right incentives to preserve the climate benefits of European forest... [as] expressed by a group of 40 scientists from all over the world working on forests [f]*”. The Co-coordinator of the EU AFOLU land use group within the UNFCCC stated “*Dr House... made a major contribution to EU policy by developing scientifically credible methods... which are also applicable worldwide... [realised] in part due to the... engage[ment] directly with policy makers and the forestry industry... We invited Dr House to present... the methods and climate implications directly to EU negotiators ahead of the EU Environment Council ministers meeting*” [g].

In 2019, one year after the new legislation, the European Commission’s assessment of member state’s FRLs [h] showed broad compliance with the regulation and, therefore, the methods in [5,6]. Where compliance was not fully achieved, the Commission asked, for example, Sweden to “*Ensure that the approach used ... reflects the continuation of sustainable forest management practices ... excluding policy assumptions on harvest rates from the FRL calculation*” as per [5,6]. The UK’s National Forestry Accounting Plan 2021-25 [h], compliant with the regulation and methods, states “*the FRL provides an accounted emission incentive for actions that lead to greater [GHG] removals compared with the continuation of existing practices and equally gives an accounted emission disincentive for actions that lead to greater emissions.*” The Head of Land Use at BEIS commented [g] “*The research and engagement efforts of Dr Jo House were instrumental in ensuring a credible science-based approach to forest reference levels was enshrined in EU law. The reduced level of hot air [false credits] in countries FRLs compared to the Kyoto Protocol [FRLs] that countries developed without these insights was significant*”, adding “*This sharpening of focus is crucial for achieving net zero*”.

5. Sources to corroborate the impact

- [a] UNEP (2019) MOP31 – Report of the 31st Meeting of the Parties to the Montreal Protocol (para. 33 - 71); UNEP (2019) OEWG-41 – Report of the 83rd Meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol (para. 51 - 54); UNEP (2019) Report of the 41st Meeting of the Open-Ended Working Group of the Parties to the Montreal Protocol (para. 15 - 44).
- [b] Brown et al (2018) [UK GHG Inventory, 1990-2016 - Report and Annexes](#); UNFCCC (2018) [UK National Inventory Submission \(NIR\)](#); Ministry of Environment, Forest and Climate Change, Government of India (2018) [2nd Biennial Update Report to the UNFCCC](#).
- [c] Testimonial Letter from BEIS (2020); SBSTA (2018) Report of the 47th Session of the Subsidiary Body for Scientific and Technological Advice to the UNFCCC: (para. 59 and associated footnote); World Meteorological Organization submission to SBSTA (Decision 51); IG3IS (2018) Integrated Global Greenhouse Gas Information System Science Implementation Plan (pp. 7, 37-38).
- [d] *Intergovernmental Panel on Climate Change (2019) Methodological Guidelines, Chapter 6: Quality Assurance/Quality Control and Verification.*
- [e] European Union (2018) [LULUCF Regulation \(EU\) No 2018/841](#); European Commission (2018) [Guidance on developing and reporting Forest Reference Levels in accordance with Regulation \(EU\) 2018/841](#); EC/JRC (2017).
- [f] EURACTIV (2017) House, [Forest accounting rules put EU’s climate credibility at risk](#); EURACTIV (2017) Larsson, Swedish Forest Industries Federation, [Short-term views on forest climate benefits is a mistake](#).
- [g] Letter from German Ministry to EU Commissioner for Climate Action and Energy (2017); Testimonial letter from EU and UNFCCC negotiator (2020); Testimonial letter from Head of Land Use and Bioenergy Science, BEIS (2020).
- [h] European Commission (2019) [Assessment of the National Forestry Accounting Plans](#); BEIS (2020) [National Forestry Accounting Plan of The UK](#).